Chapter 8 - Dose to the Public and Biota

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Chapter Highlights

The potential radiological dose to the public from Idaho National Engineering and Environmental Laboratory (INEEL) operations was evaluated to determine compliance with pertinent regulations and limits. Two different computer models were used to estimate doses: CAP-88 and the mesoscale diffusion (MDIFF) air dispersion model. CAP-88 is required by the U.S. Environmental Protection Agency to demonstrate compliance with the Clean Air Act. The National Oceanic and Atmospheric Administration Air Resources Laboratory-Field Research Division developed MDIFF to evaluate dispersion of pollutants in arid environments such as those found at the INEEL. The maximum calculated dose to an individual by either of the methods was well below the applicable radiation protection standard of 10 mrem/yr. The dose to the maximally exposed individual, as determined by the CAP-88 program, was 0.035 mrem (0.35 μSv). The dose calculated using the MDIFF values was 0.024 mrem (0.24 μSv). The maximum potential population dose to the approximately 276,979 people residing within a 80-km (50-mi) radius of any INEEL facility was 0.022 person-rem (2.2×10^{-4} person-Sv), well below that expected from exposure to background radiation.

Using the maximum radionuclide concentrations in collected waterfowl, game animals, and marmots, a maximum potential dose from ingestion was calculated. The maximum potential dose for each was estimated to be 0.002 mrem (0.02 μSv) for waterfowl, 0.099 mrem (0.99 μSv) for game animals, and 0.006 mrem (0.06 μSv) for marmots.

The potential dose to aquatic and terrestrial biota from contaminated soil and water was also evaluated, using a graded approach. Based on this approach, there is no evidence that INEEL related contamination is having an adverse impact on populations of plants and/or animals.

8. DOSE TO THE PUBLIC AND BIOTA

It is the policy of the U.S. Department of Energy (DOE) "To implement sound stewardship practices that are protective of the air, water, land, and cultural and ecological resources impacted by DOE operations and by which DOE cost-effectively meets or exceeds compliance with applicable environmental; public health; and resource protection laws, regulations, and DOE requirements" (DOE 2003). DOE Order 5400.5 further states, "It is also a DOE objective that potential exposures to members of the public be as far below the limits as is reasonably achievable..." (DOE 1993). This chapter describes the dose to members of the public and to the environment based on the 2003 radionuclide concentrations from operations at the Idaho National Engineering and Environmental Laboratory (INEEL).

8.1 General Information

Individual radiological impacts to the public surrounding the INEEL remain too small to be measured by available monitoring techniques. To show compliance with federal regulations established to ensure public safety, the dose from INEEL operations was calculated using the reported amounts of radionuclides released during the year from INEEL facilities (see Chapter 4) and appropriate air dispersion computer codes. During 2003, this was accomplished for the radionuclides summarized in Table 4-2.

The following estimates were calculated:

- The effective dose equivalent to the hypothetical maximally exposed individual (MEI), as defined by the National Emission Standards for Hazardous Air Pollutants (NESHAP) regulations, using the CAP-88 computer code as required by the regulation (Cahki and Parks 2000);
- The effective dose equivalent to the MEI residing offsite using dispersion values from the mesoscale diffusion (MDIFF) model (Sagendorf et al. 2001) to comply with DOE Orders; and
- The collective effective dose equivalent (population dose) for the population within 80 km (50 mi) of any INEEL facility to comply with DOE Order 5400.5. The estimated population dose was based on the effective dose equivalent calculated from the MDIFF air dispersion model for the MEI.

In this chapter, the term dose refers to effective dose equivalent unless another term is specifically stated. Dose was calculated by summing the effective dose equivalents from each exposure pathway. Effective dose equivalent includes doses received from both external and internal sources and represents the same risk as if an individual's body were uniformly irradiated. U.S. Environmental Protection Agency (EPA) dose conversion factors and a 50-year integration period was used in calculations in combination with the MDIFF air dispersion model for internally deposited radionuclides (Eckerman et al. 1988) and for radionuclides deposited on the ground surface (Eckerman and Ryman 1993). The CAP-88 computer code uses dose and risk tables developed by the EPA. No allowance is made in the dose calculations using MDIFF for shielding by housing materials, which is estimated to reduce the dose by about 30 percent; or less than year-round occupancy time in the community. The CAP-88 computer code does not include shielding by housing materials, but it does include a factor to allow for shielding by surface soil contours from radioactivity on the ground surface.

Of the potential exposure pathways by which radioactive materials from INEEL operations could be transported offsite (see Figure 3-1), atmospheric transport is the principal potential pathway for exposure to the surrounding population. This is because winds can carry airborne radioactive material rapidly and some distance from its source. The water pathways are not considered major contributors to dose because no surface water flows off the INEEL and no radionuclides from the INEEL have been found in drinking water wells offsite. Because of these factors, the MEI dose is determined through the use of computer codes of atmospheric dispersion of airborne materials.

8.2 Maximum Individual Dose - Airborne Emissions Pathway

Summary of Computer Codes

The NESHAP, as outlined in Title 40, Code of Federal Regulations (CFR), Part 61 (40 CFR Part 61), Subpart H, requires the demonstration that radionuclides other than radon released to air from any DOE nuclear facility do not result in a dose to the public of greater than 10 mrem/yr (EPA 2001). This includes releases from stacks and diffuse sources. The EPA requires the use of an approved computer code to demonstrate compliance with 40 CFR Part 61. The INEEL uses the code CAP-88 as recommended in 40 CFR 61 to demonstrate NESHAP compliance.

The National Oceanic and Atmospheric Administration Air Resources Laboratory-Field Research Division (NOAA ARL-FRD) developed a mesoscale air dispersion model called MDIFF (formerly known as MESODIF) (Sagendorf et al. 2001) around 1970. The MDIFF diffusion curves were developed by the NOAA ARL-FRD from tests in arid environments (e.g., the INEEL and the Hanford Site in eastern Washington). The MDIFF curves are more appropriate for estimating dose to the public caused by INEEL emissions than those used by the CAP-88 code. The MDIFF code is a dispersion model only and does not account for plume depletion and radioactive decay.

The MDIFF model has been in use for almost 40 years to calculate total integrated concentrations (TICs) that are then used to calculate the dose to members of the public residing near the INEEL. In previous years, doses calculated from the MDIFF TICs have been somewhat higher than doses calculated using CAP-88. Differences between the two computer codes were discussed in detail in the 1986 annual report (Hoff et al. 1987). The primary difference is the atmospheric dispersion portion of the codes. CAP-88 makes its calculations based on the joint frequency of wind conditions from a single wind station located near the source in a straight line from that source and ignores recirculation. MDIFF calculates the trajectories of a puff using wind information from 36 towers in the Upper Snake River Plain. This allows for more accurate and site-specific modeling of the movement of a release using prevailing wind conditions between time of the release and the time that the plume leaves the INEEL boundary. For this reason, the two computer codes may not agree on the location of the MEI or the magnitude of the maximum dose.

The offsite concentrations calculated using both computer codes were compared to actual monitoring results using the radionuclide antimony-125 at offsite locations in 1986, 1987, and 1988 (Hoff et al. 1987, Chew and Mitchell 1988, Hoff et al. 1989). Concentrations calculated for several locations using the MDIFF TICs showed good agreement (within a factor of 2) with concentrations from actual measurements, with the model calculations generally predicting concentrations higher than those measured. The original computer code (MESODIF) was extensively studied and validated, and compared to other models in the mid-1980s (Lewellen, et al. 1985, Start et al. 1985, Sagendorf and Fairobent 1986).

CAP-88 Computer Code

The dose from INEEL airborne releases of radionuclides calculated to demonstrate compliance with NESHAP are published in the *National Emissions Standards for Hazardous Air Pollutants-Calendar Year 2003 INEEL Report for Radionuclides* (DOE-ID 2004). For these calculations, 63 potential maximum locations were evaluated. The CAP-88 computer code predicted the highest dose to be at Frenchman's Cabin, located at the southern boundary of the INEEL. This location is only inhabited during portions of the year, but it must be considered as a potential MEI location according to the NESHAP. At Frenchman's Cabin, an effective dose equivalent of 0.035 mrem (0.35 μSv) was calculated. The facilities making the largest contributions to this dose were the Idaho Nuclear Technology and Engineering Center (INTEC) at 60 percent, the Test Reactor Area (TRA) at 28 percent, the Test Area North (TAN) at 8 percent and the Radioactive Waste Management Complex (RWMC) at 4 percent. The dose of 0.035 mrem (0.35 μSv) is well below the whole body dose limit of 10 mrem (100 μSv) for airborne releases of radionuclides established by 40 CFR 61.

MDIFF Model

Using data gathered continuously at 36 meteorological stations on and around the INEEL and the MDIFF model, the NOAA ARL-FRD prepares a mesoscale map (Figure 8-1) showing the calculated 2003 time integrated concentrations. These TICs are based on a unit release rate weighted by percent contribution for each of eight INEEL facilities (Argonne National Laboratory-West [ANL-W], Central Facilities Area [CFA], INTEC, Naval Reactors Facility [NRF], Power Burst Facility [PBF], RWMC, TRA, and TAN). To create the isopleths shown in Figure 8-1, the TIC values are contoured. Average air concentrations (in curies per cubic meter [Ci/m^3]) for a radionuclide released from a facility are estimated from a TIC isopleth (line of equal air concentration) in Figure 8-1. To calculate the average air concentration, the TIC is multiplied by the quantity of the radionuclide released (in curies [Ci]) during the year and divided by the number of hours in a year squared (8760 hr)^2 or 7.67 x 10^7 hr^2. This does not account for plume depletion, radioactive decay, or in-growth or decay of radioactive progeny.

In 2000, a revision to the methods and values used for the calculation of the MEI dose from the MDIFF TIC values was undertaken. Values for the deposition and plant uptake rates of radionuclides, most noticeably radioiodines, were modified to reflect present operations and current values in use. The most notable change, mathematically, is the increase of the iodine-129 (^{129}I) deposition velocity from 0.01 m/sec to 0.035 m/sec, as the emitted radioiodines went from predominantly organic in nature to elemental. These changes resulted in a mathematical increase in the amount of radionuclides deposited on the ground and available for plant uptake. This increase in deposited radionuclides leads to a corresponding net increase in the ingestion dose.

The MDIFF model predicted that the highest TIC for radionuclides in air at a location with a year-round resident during 2003 would have occurred at Frenchman's Cabin. The maximum hypothetical dose was calculated for an adult resident at that location from inhalation of air, submersion in air, ingestion of radioactivity on leafy vegetables, and exposure because of deposition of radioactive particles on the ground. The calculation was based on data presented in Table 4-2 and the grid used to produce Figure 8-1.

Using the largest calculated TIC for each facility (Table 8-1) at the location inhabited by a full-time resident, and allowing for radioactive decay and plume depletion during the transit of

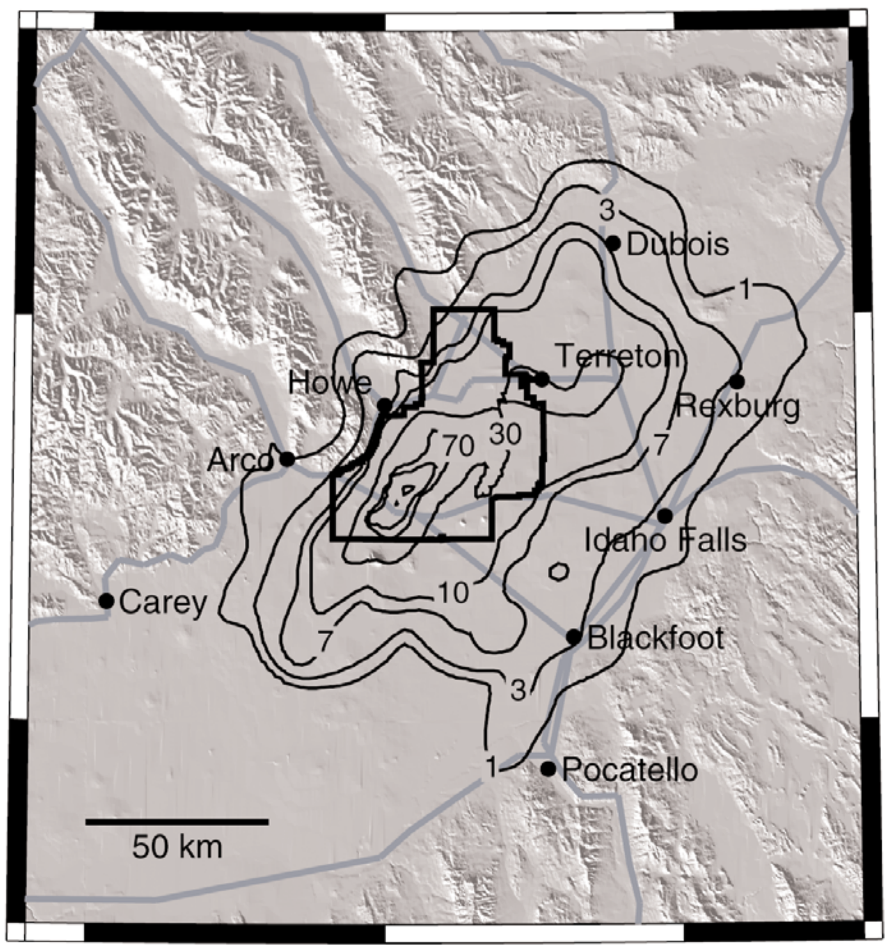

Figure 8-1. Average mesoscale isopleths of total integrated concentrations at ground level normalized to unit release rate from all INEEL facilities.[a]

a. Concentrations are times 10^{-9} hours squared per meter cubed (x 10^{-9} hr^2/m^3).

Table 8-1. Total integrated concentration, travel time, and distance from each facility to the MEI location.

Facility	Total Integrated Concentration (hr^2/m^3)	Travel Time hours	Distance km (miles)
AMWTF	1.44×10^{-7}	0.46	7.9 (4.92)
ANL-W	5.31×10^{-9}	2.34	23.1 (23.12)
CFA	9.30×10^{-8}	0.84	14.5 (9.03)
INTEC	4.66×10^{-8}	1.31	18.8 (11.65)
NRF	4.08×10^{-8}	1.72	27.1 (16.82)
PBF	3.43×10^{-8}	1.49	20.4 (12.68)
RWMC	1.44×10^{-7}	0.46	7.9 (4.92)
TAN	1.84×10^{-8}	3.81	56.4 (35.06)
TRA	3.72×10^{-8}	1.13	19.0 (11.85)

the radionuclides from each facility to the location of the MEI (at Frenchman's Cabin), the potential annual effective dose equivalent from all radionuclides released was calculated to be 0.024 mrem (0.24 µSv) (Table 8-2). This dose is well below the whole body dose limit of 10 mrem set in the 40 CFR 61 for airborne releases of radionuclides.

For 2003, the inhalation pathway was the primary route of exposure and accounted for 73 percent of the total dose, followed by ingestion at 21 percent, and immersion at 6 percent. Deposition accounted for only 0.12 percent of the dose.

Radionuclide releases for 2003 are presented in Figure 8-2. The noble gas krypton-85 (^{85}Kr) accounted for approximately 75 percent of the total release, followed by tritium with 14 percent, and argon-41 (^{41}Ar) at 10 percent of the total. The noble gases xenon-133 (^{133}Xe)

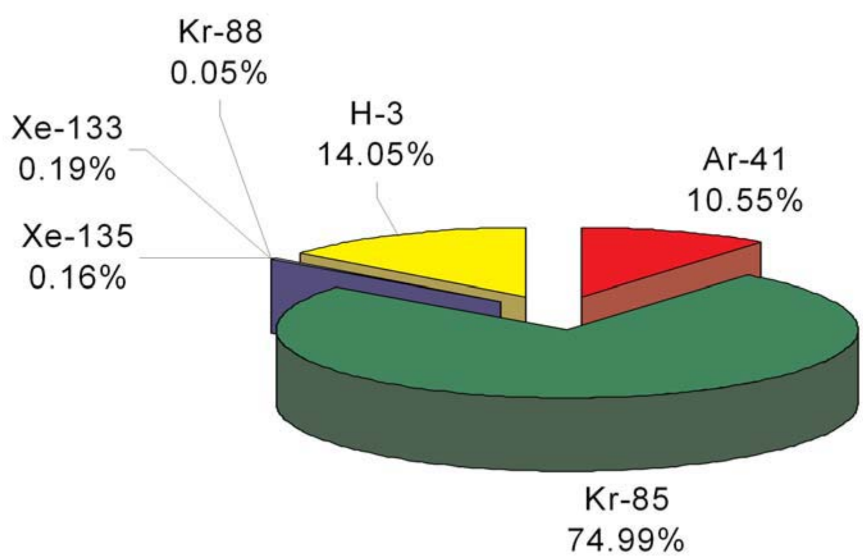

Figure 8-2. Radionuclides released to the environmental (2003).

Table 8-2. Maximum individual effective dose equivalent as calculated from MDIFF model results (2003).

	Radionuclide Concentration in Air at Maximum Offsite Location[b]	Maximum Effective Dose Equivalent	
Radionuclide[a]	**(Ci/m^3)**	**mrem**	**mSv**
^{241}Pu	1.13×10^{-17}	9.64×10^{-4}	9.64×10^{-6}
^{90}Sr + Dd	2.31×10^{-17}	2.51×10^{-3}	2.51×10^{-5}
^{129}I[c]	1.75×10^{-17}	5.77×10^{-3}	5.77×10^{-5}
^{137}Cs + D[c,d]	1.56×10^{-16}	6.74×10^{-3}	6.74×10^{-5}
^{239}Pu	4.09×10^{-19}	1.82×10^{-3}	1.82×10^{-5}
^{41}Ar	1.77×10^{-13}	1.34×10^{-3}	1.34×10^{-5}
^{240}Pu	2.28×10^{-19}	1.01×10^{-3}	1.01×10^{-5}
^{241}Am	1.56×10^{-19}	1.04×10^{-3}	1.04×10^{-5}
^{238}Pu	1.02×10^{-19}	4.13×10^{-4}	4.13×10^{-6}
^{131}I	1.16×10^{-16}	9.46×10^{-4}	9.46×10^{-6}
^{244}Cm	1.38×10^{-19}	5.11×10^{-4}	5.11×10^{-6}
^{60}Co	3.89×10^{-17}	4.61×10^{-4}	4.61×10^{-6}
All Others	NA	3.54×10^{-4}	3.54×10^{-6}
Total		**2.39×10^{-2}**	**2.39×10^{-4}**

a. Table includes only radionuclides that contribute a dose of 1.0 × 10-5 mrem or more.
b. Estimate of radionuclide decay is based on a transport time from each facility using the distance to MEI location and the average wind speed in that direction from each facility.
c. Concentration adjusted for plume depletion.
d. When indicate (+D), the contribution of progeny decay products was also included in the dose calculations.

and xenon-135 (^{135}Xe) each contributed 0.2 percent, followed by krypton-88 (^{88}Kr) at 0.1 percent. However, because these are noble gases they contribute very little to the cumulative dose (affecting immersion only). Other than ^{41}Ar, the radionuclides contributing to the overall dose were 0.004 percent or less of the total radionuclides released.

The largest contributor to the MEI dose was cesium-137 (^{137}Cs), accounting for 28 percent of the total dose (Figure 8-3). This was followed by ^{129}I at 24 percent, strontium-90 (^{90}Sr) at 10.5 percent, plutonium-239 [^{239}Pu] at 8 percent, and argon-41 (^{41}Ar) at 6 percent. Other plutoniums (plutonium-238 [^{238}Pu], plutonium-240 [^{240}Pu] and plutonium-241 [^{241}Pu]) contributed to the dose at 1.7, 4.2 and 4.0 percent, respectively. Americium-41 accounted for 4.3 percent of the dose, with all others combined contributing 9.3 percent .

The respective contribution to the overall dose by facility is as follows: INTEC (64 percent), TRA (23 percent), TAN (12 percent), and CFA (0.4 percent). The PBF and NRF each contributed approximately 0.02 percent of the 2003 total dose, while RWMC contributed about 0.4% and ANL-W contributed 0.005 percent. The percent contribution calculated for NRF is based on the assumption that all gross alpha is ^{239}Pu and all gross beta is ^{90}Sr.

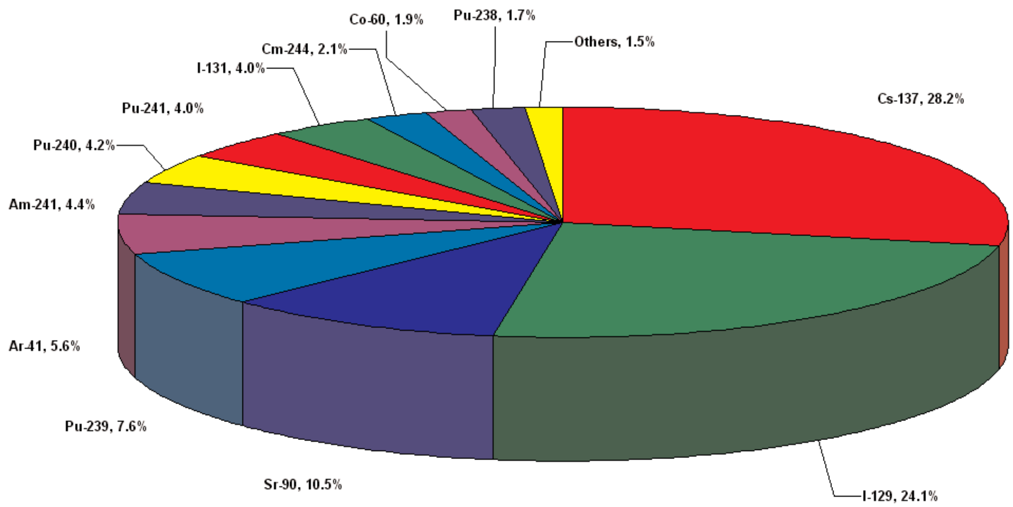

Figure 8-3. Radionuclides contributing to maximum individual dose (as calculated using the MDIFF air dispersion model) (2003).

The calculated maximum dose resulting from INEEL operations is still a small fraction of the average dose received by individuals in southeastern Idaho from cosmic and terrestrial sources of naturally occurring radiation found in the environment. The total annual dose from all natural sources is estimated at approximately 363 mrem (Table 7-11).

Table 8-3 summarizes the calculated annual effective dose equivalents for 2003 from INEEL operations using both the CAP-88 and MDIFF air dispersion computer codes. A comparison is shown between these doses and the EPA airborne pathway standard and the estimated dose from natural background.

8.3 80 Kilometer (50 Mile) Population Dose

As with the calculation of the maximum individual dose, the determination of the population dose also underwent changes in 2000. Using the power of a geographical information system (ArcView), annual population no longer needs to be distributed using growth estimations and a specialized computer code. In addition to this simplification, the population dose is now calculated for the population within an 80 km (50 mi) radius of any INEEL facility. This takes into account the changes in facility operations, in that the INTEC is not always the single largest contributor of radionuclides released.

An estimate was made of the collective effective dose equivalent, or population dose, from inhalation, submersion, ingestion, and deposition resulting from airborne releases of radionuclides from the INEEL. This collective dose included all members of the public within

Table 8-3. Summary of annual effective dose equivalents because of INEEL operations (2003).

	Maximum Dose to an Individual[a]		Population Dose
	CAP-88[b]	**MDIFF[c]**	**MDIFF**
Dose	0.035 mrem (3.5×10^{-4} mSv)	0.024 mrem (2.4×10^{-4} mSv)	0.022person-rem (2.2×10^{-4} person-Sv)
Location	Frenchman's Cabin	Frenchman's Cabin	Area within 80 km (50 mi) of any INEEL facility
Applicable radiation protection standard[d]	10 mrem (0.1 mSv)	10 mrem (0.1 mSv)	No standard
Percentage of standard	0.35 percent	0.24 percent	No standard
Natural background	363 mrem (3.6 mSv)	363 mrem (3.6 mSv)	100,540 person-rem (1,005 person Sv)
Percentage of background	0.01 percent	0.007 percent	0.00002 percent

a. Hypothetical dose to the maximally exposed individual residing near the INEEL.
b. Effective dose equivalent calculated using the CAP-88 code.
c. Effective dose equivalent calculated using the MDIFF air dispersion model. MDIFF calculations do not consider occupancy time or shielding by buildings.
d. Although the DOE standard for all exposure models is 100 mrem/yr as given in DOE Order 5400.5, DOE guidance states that DOE facilities will comply with the EPA standard for the airborne pathway of 10 mrem/yr.

80 km (50 mi) of an INEEL facility. The population dose was calculated in a spreadsheet program that multiplies the average TIC for the county census division (in hours squared per cubic meter) by the population in each census division within that county division and the normalized dose received at the location of the MEI (in rem per year per hour squared per meter cubed). This gives an approximation of the dose received by the entire population in a given county division (Table 8-4).

The dose received per person is obtained by dividing the collective effective dose equivalent by the population in that particular census division. This calculation overestimates dose because the model conservatively does not account for radioactive decay of the isotopes during transport over distances greater than the distance from each facility to the residence of the MEI located at Frenchman's Cabin. Idaho Falls, for example, is about 50 km (31 mi) from the nearest facility (ANL-W) and 80 km (50 mi) from the farthest. Neither residence time nor shielding by housing was considered when calculating the MEI dose on which the collective effective dose equivalent is based. The calculation also tends to overestimate the population doses because they are extrapolated from the dose computed for the location of the potential MEI. This individual is potentially exposed through ingestion of contaminated leafy garden vegetables grown at that location.

Table 8-4. Dose to population within 80 km (50 mi) of the INEEL facilities (2003).

Census Division[a]	Population[b]	Population Dose	
		Person-rem	Person-Sv
Aberdeen	3,356	4.11×10^{-5}	4.11×10^{-7}
Alridge	633	3.66×10^{-6}	3.66×10^{-8}
American Falls	3,232	2.04×10^{-5}	2.04×10^{-7}
Arbon (part)	29	5.94×10^{-7}	5.94×10^{-9}
Arco	2,381	1.85×10^{-3}	1.85×10^{-5}
Atomic City (division)	3,074	1.13×10^{-5}	1.13×10^{-7}
Blackfoot	13,302	1.04×10^{-3}	1.04×10^{-5}
Carey (part)	1,034	6.85×10^{-5}	6.85×10^{-7}
East Clark	73	8.11×10^{-6}	8.11×10^{-8}
Firth	3,368	1.50×10^{-4}	1.50×10^{-6}
Fort Hall (part)	1,990	7.51×10^{-5}	7.51×10^{-7}
Hailey-Bellevue (part)	5	6.78×10^{-12}	6.78×10^{-14}
Hamer	2,332	3.36×10^{-3}	3.36×10^{-5}
Howe	331	6.23×10^{-4}	6.23×10^{-6}
Idaho Falls	78,324	4.02×10^{-3}	4.02×10^{-5}
Idaho Falls, west	1,824	4.62×10^{-4}	4.62×10^{-6}
Inkom (part)	580	4.35×10^{-6}	4.35×10^{-8}
Island Park (part)	82	9.08×10^{-6}	9.08×10^{-8}
Leadore (part)	5	6.07×10^{-9}	6.07×10^{-11}
Lewisville-Menan	4,002	9.32×10^{-4}	9.32×10^{-6}
Mackay (part)	1,136	2.50×10^{-7}	2.50×10^{-9}
Moody (part)	4,753	1.36×10^{-4}	1.36×10^{-6}
Moreland	9,539	1.76×10^{-3}	1.76×10^{-5}
Pocatello (part)	79,140	2.05×10^{-3}	2.05×10^{-5}
Rigby	11,788	8.54×10^{-4}	9.54×10^{-6}
Ririe	1,486	1.80×10^{-5}	1.80×10^{-7}
Roberts	1,696	8.52×10^{-4}	8.52×10^{-6}
Shelley	7,342	4.55×10^{-4}	4.55×10^{-6}
South Bannock (part)	295	6.29×10^{-6}	6.29×10^{-8}
St. Anthony (part)	2,260	2.33×10^{-4}	2.33×10^{-6}
Sugar City	5,378	8.56×10^{-4}	8.56×10^{-6}
Swan Valley (part)	5,132	1.61×10^{-5}	1.61×10^{-7}
Thornton	20,112	1.52×10^{-3}	1.52×10^{-5}
Ucon	5,773	4.91×10^{-4}	4.91×10^{-6}
West Clark	1,166	1.55×10^{-4}	1.55×10^{-6}
Totals	**276,979**	**0.022**	**2.2×10^{-4}**

a. (Part) means only a part of the county census division lies within the 80-km (50-mi) radius of a major INEEL facility.

b. Population based on 2000 Census Report for Idaho and updated to 2004 based on county population growth from 1960 to 2000.

The 2003 MDIFF TIC used for calculation of the population dose within each county division were obtained by averaging the results from appropriate census divisions contained within those county divisions. The total population dose is the sum of the population doses for the various county divisions (Table 8-4). The estimated potential population dose was 0.022 person-rem (2.2×10^{-4} person-Sv) to a population of approximately 276,979. When compared with an approximate population dose of 100,540 person-rem (1,005 person-Sv) from natural background radiation, this represents an increase of only about 0.00005 percent. The dose of 0.022 person-rem can also be compared to the following estimated population doses for the same size population: 33,250 person-rem for medical diagnostic procedures, about 970 person-rem from exposure to highway and road construction materials, or 2.8 person-rem from nuclear power generation. The largest collective doses are found in the Idaho Falls and Hamer census divisions. Idaho Falls is high because of its greater population; Hamer is relatively high because most of this division lies in the predominant wind direction from the INEEL.

8.4 Individual Dose - Game Ingestion Pathway

The potential dose an individual may receive from the occasional ingestion of meat from game animals continues to be investigated at the INEEL. Such studies include the potential dose to individuals who may eat (a) waterfowl that reside briefly at waste disposal ponds at TRA, INTEC, and ANL-W that used for the disposal of low-level radioactive wastes and (b) game birds and game animals that may reside on or migrate across the INEEL.

Waterfowl

A study was initiated in 1994 to obtain data on the potential doses from waterfowl using INEEL waste disposal ponds. This study focused on the two hypalon-lined evaporation ponds at TRA that replaced the percolation ponds formerly used for disposal of wastes at that facility (Warren et al. 2001).

In the fall of 2003, eight ducks were collected from waste ponds on the INEEL and three were collected from offsite locations (Mud Lake, Idaho) as controls. Of the waterfowl collected from the INEEL, five were collected from waste ponds containing radionuclides at the TRA and three from the waste pond at ANL-W. The maximum potential dose from eating 225 g (8 oz) of meat from ducks collected in 2003 is presented in Table 8-5. Radionuclide concentrations driving these doses are reported in Table 7-6. Doses from consuming waterfowl are based on the assumption that ducks are eaten immediately after leaving the ponds.

The maximum potential dose of 0.002 mrem (0.02 μSv) from these waterfowl samples is substantially below the 0.89 mrem (8.9 μSv) committed effective dose equivalent estimated from the most contaminated ducks taken from the evaporation ponds between 1993 and 1998 (Warren et al. 2001).

Table 8-5. Maximum annual potential dose from ingestion of edible waterfowl tissue using INEEL waste disposal ponds in 2003.[a]

Radionuclide	Maximum Dose [b] (mrem/yr)	Background Dose [c] (mrem/yr)
^{141}Ce	1.04×10^{-4}	
^{137}Cs	3.39×10^{-4}	
^{60}Co	1.00×10^{-4}	9.89×10^{-5}
^{95}Nb		9.13×10^{-5}
^{241}Am	3.33×10^{-4}	
$^{239/240}$Pu	3.65×10^{-4}	
^{90}Sr	4.29×10^{-4}	4.68×10^{-4}
Total Dose	**1.67×10^{-3}**	**6.58×10^{-4}**

a. Committed (50-yr) effective dose equivalent from consuming 225 g (8 oz) of edible (muscle) waterfowl tissue. Dose conversion factors are from EPA Federal Guidance Report No. 13 (EPA-402-R-99-001).

b. Doses are calculated on maximum radionuclide concentrations in eight different waterfowl collected at INEEL waste disposal ponds and are therefore worst case doses.

c. Background doses calculated from maximum background concentrations to maintain comparability of data.

Mourning Doves

No mourning doves were collected in 2003.

Big Game Animals

A conservative estimate of the potential whole-body dose that could be received from an individual eating the entire muscle (26,000 g [952 oz]) and liver mass (500 g [17.6 oz]) of an antelope with the highest levels of radioactivity found in these animals was estimated at 2.7 mrem in a study on the INEEL from 1976-1986 (Markham et al. 1982). Game animals collected at the INEEL during the past few years have shown much lower concentrations of radionuclides. Based on the highest concentration of radionuclides found in a game animal during 2003, the potential dose was approximately 0.045 mrem (0.45 µSv). This includes maximum doses from both iodine-131 and ^{137}Cs in muscle and liver tissue from a single pronghorn collected between CFA and INTEC on the INEEL (see Table 7-4).

Yellow-bellied Marmots

During the 2003, three marmots were collected from the Subsurface Disposal Area of the RWMC. These samples were biased toward areas of potential highest contamination. Three marmots were also collected from the Pocatello Zoo and one from Tie Canyon in Swan Valley, as controls. Each marmot was dissected into three samples, the edible portion (muscle tissue), viscera, and the remainder (skin, fur, bones). The potential dose from eating 225 g (8 oz.) of the most contaminated edible portions of the marmots collected in 2003 was 0.006 mrem (0.06 μSv).

The contribution of game animal consumption to the population dose has not been calculated because only a limited percentage of the population hunts game, few of the animals killed have spent time on the INEEL, and most of the animals that do migrate from the INEEL would have reduced concentrations of radionuclides in their tissues by the time they were harvested (Halford et al. 1983). The total population dose contribution from these pathways would, realistically, be less than the sum of the population doses from inhalation of air, submersion in air, ingestion of vegetables, and deposition on soil.

8.5 Biota Dose Assessment

Introduction

The impact of environmental radioactivity at the INEEL on nonhuman biota was assessed using the graded approach procedure detailed in *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2002) and the associated software, RESRAD-Biota (ISCORS 2004). The graded approach evaluates the impacts of a given set of radionuclides on aquatic and terrestrial ecosystems by comparing available concentration data in soils and water with biota concentration guides (BCGs). A BCG is defined as the environmental concentration of a given radionuclide in soil or water that, under the assumptions of the model, would result in a dose rate less than 1 rad/d (10 mGy/d) to aquatic animals or terrestrial plants or 0.1 rad/d (1 mGy/d) to terrestrial animals. If the sum of the measured environmental concentrations divided by the BCGs (the combined sum of fractions) is less than one, no negative impact to populations of plants or animals is expected. No doses are calculated unless the screening process indicates a more detailed analysis is necessary.

The approach is graded because it begins the evaluation using conservative default assumptions and maximum values for all currently available data. Failure at this general screening step does not necessarily imply harm to organisms. Instead, it is an indication that more realistic model assumptions may be necessary. Several specific steps for adding progressively more realistic model assumptions are recommended. After applying the recommended changes at each step, if the combined sum of fractions is still greater than one, the graded approach recommends evaluating the next step. The steps can be summarized as:

1. Consider using mean concentrations of radionuclides rather than maxima;

2. Consider refining the evaluation area;

3. Consider using site-specific information for lumped parameters, if available;

4. Consider using a correction factor other than 100 percent for residence time and spatial usage in favor of more realistic assumptions;

5. Consider developing and applying more site-specific information about food sources, uptake, and intake; and

6. Conduct a complete site-specific dose analysis. This is may be a large study, measuring or calculating doses to individual organisms, estimating population level impacts, and, if doses in excess of the limits are present, culminating in recommendations for mitigation.

Each step of this graded approach requires appropriate justification before it can be applied. For example, before using the mean concentration, assessors must discuss why the maximum concentration is not representative of the radionuclide concentration to which most members of the plant or animal population are exposed.

Evaluations beyond the initial general screening require assessors to make decisions about assessment areas, organisms of interest, and other factors. Of particular importance for the terrestrial evaluation portion of the 2003 biota dose assessment is the division of the INEEL into evaluation areas based on potential soil contamination and habitat types (Figure 8-4). Details and justification are provided in Morris (2003).

The graded approach (DOE 2002) and RESRAD-Biota (ISCORS 2004) are designed to evaluate certain common radionuclides. Thus, this biota dose assessment evaluated potential doses from radionuclides detected in soil or water on the INEEL that are also included in the graded approach (Table 8-6).

Aquatic Evaluation

For this analysis, maximum effluent data were used when actual pond water samples were not available. These data are assumed to overestimate actual pond water concentrations because of dilution in the larger volume of the pond. In the absence of measured pond sediment concentrations, the software calculates sediment concentrations based on a conservative sediment distribution coefficient. The only available radionuclide specific concentrations were for iodine-129 (^{129}I) in INTEC effluents, tritium (^{3}H) in the ANL-W industrial waste pond and ^{90}Sr in TAN effluents (Table 8-7) (see DOE 2002 for a detailed description of the assessment procedure). These data were combined in a Site-wide general screening analysis. The combined sum of fractions was less than one and passed the screening test (Table 8-7).

Terrestrial Evaluation

For the initial terrestrial evaluation we used maximum concentrations from the management and operating (M&O) contractor 2003 soil sampling (Figure 8-4, Table 8-8) (see DOE 2002 for a detailed description of the assessment procedure). These concentrations failed the initial screen (Table 8-8, First Screening) because of high ^{137}Cs concentrations in single samples from evaluation Areas 6 and 15 (Figures 8-5 and 8-6). For this reason, Areas 6 and 15 were sequentially removed from the analysis and the remaining maximum soil concentrations used (Table 8-8, Second and Third Screenings). Evaluation of potential harm to nonhuman terrestrial biota from maximum detected soil and water concentrations over the entire INEEL, with the exception of evaluation Areas 6 and 15, resulted in a combined sum of fractions less than one.

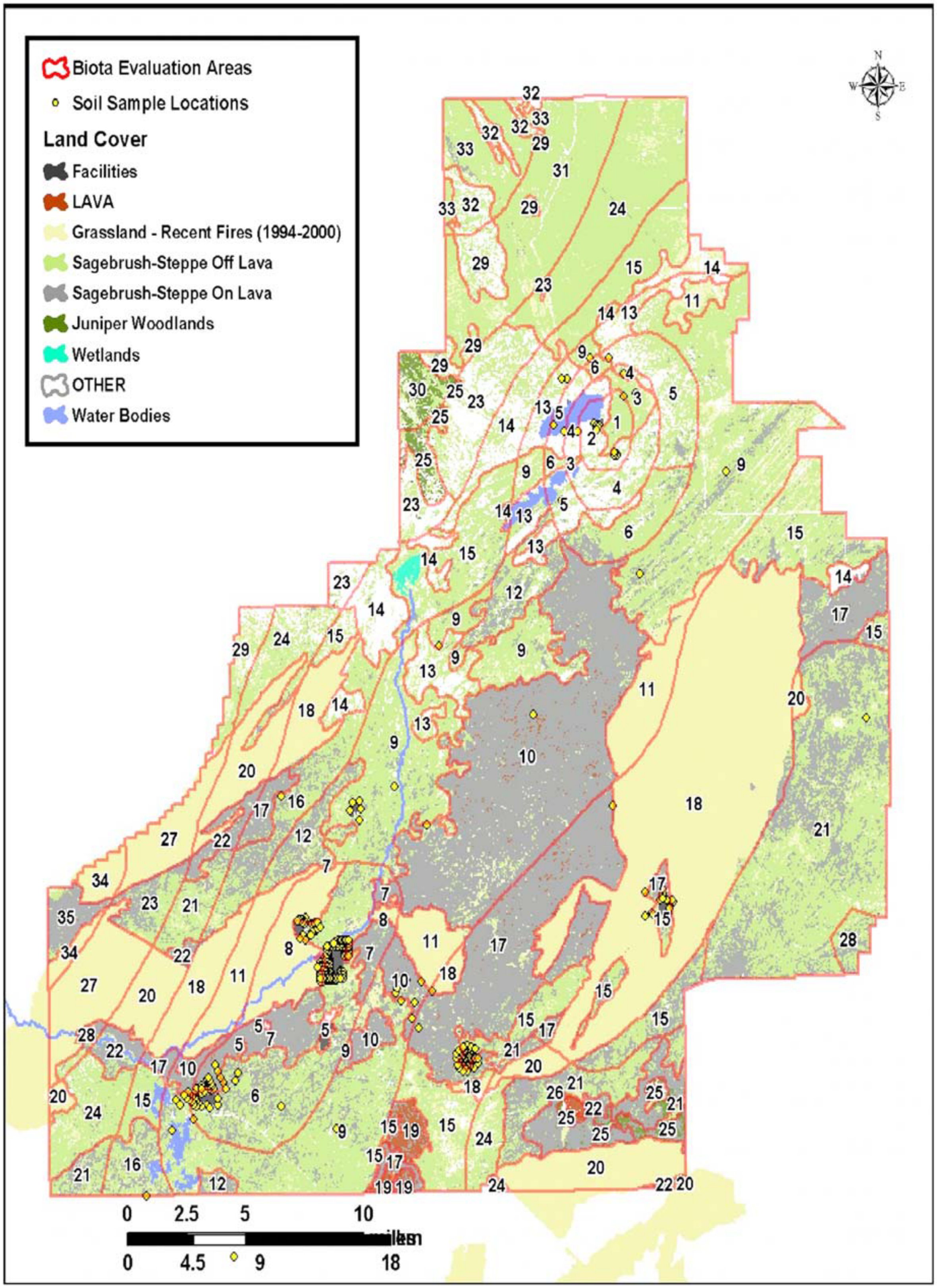

Figure 8-4. Evaluation areas and current soil sampling locations on the INEEL.

Table 8-6. Radionuclides that can currently be evaluated using the Graded Approach (DOE 2002, Morris 2003) compared to those detected in soil or water on the INEEL in 2003. Radionuclides in **bold type** are present in both lists and were included in this assessment**.**

Graded Approach	Detected
^{241}Am[a]	**^{241}Am**
^{144}Ce	**^{137}Cs**
^{135}Cs	**^{3}H**
^{137}Cs	**^{129}I**
^{60}Co	**$^{239/240}$Pu**[b]
^{154}Eu	**^{226}Ra**
^{155}Eu	**^{90}Sr**
^{3}H	**^{232}Th**
^{129}I	**$^{233/234}$U**[c]
^{131}I	**^{235}U**
^{239}Pu	**^{238}U**
^{226}Ra	
^{228}Ra	
^{125}Sb	
^{90}Sr	
^{99}Tc	
^{232}Th	
^{233}U	
^{234}U	
^{235}U	
^{238}U	
^{65}Zn	
^{95}Zr	

a. Radionuclides in **bold type** are present in both lists and were included in this assessment.
b. Analyzed as ^{239}Pu.
c. Analyzed as ^{233}U.

Table 8-7. Effluent data, biota concentration guides, and sums of fractions, and combined sums of fractions for biota assessment of aquatic ecosystems on the INEEL. (See DOE 2002 for definitions and a detailed description of the procedure.)

Nuclide	Water BCG[a] (pCi/L)	Effluent Concentration (pCi/L)	Partial Fraction[b]	Sediment BCG (pCi/g)	Calculated Sediment Concentration[c] (pCi/g)	Partial Fraction[d]	Sum of Fractions[e]
First Screening							
^{3}H	3×10^{8}	3.60×10^{3}	1.36×10^{-5}	4×10^{5}	3.60×10^{-3}	9.63×10^{-9}	1.36×10^{-5}
^{129}I	$4.\times10^{4}$	1.00×10^{-1}	2.60×10^{-6}	$3.\times10^{4}$	1.00×10^{-3}	3.50×10^{-8}	2.64×10^{-6}
^{90}Sr	300	8.30	0.03	60	0.25	4.28×10^{-4}	0.03
						Combined Sum of Fractions[f]	**.03**

a. Biota concentration guide.
b. Effluent concentration/water BCG.
c. Calculated by the RadBCG spreadsheet based on the effluent concentration (DOE 2003).
d. Calculated sediment concentration/sediment BCG.
e. Sum of the partial fractions.
f. Sum of the sums of fractions. If the combined sum of fractions is less than one, the site passes the screening evaluation.

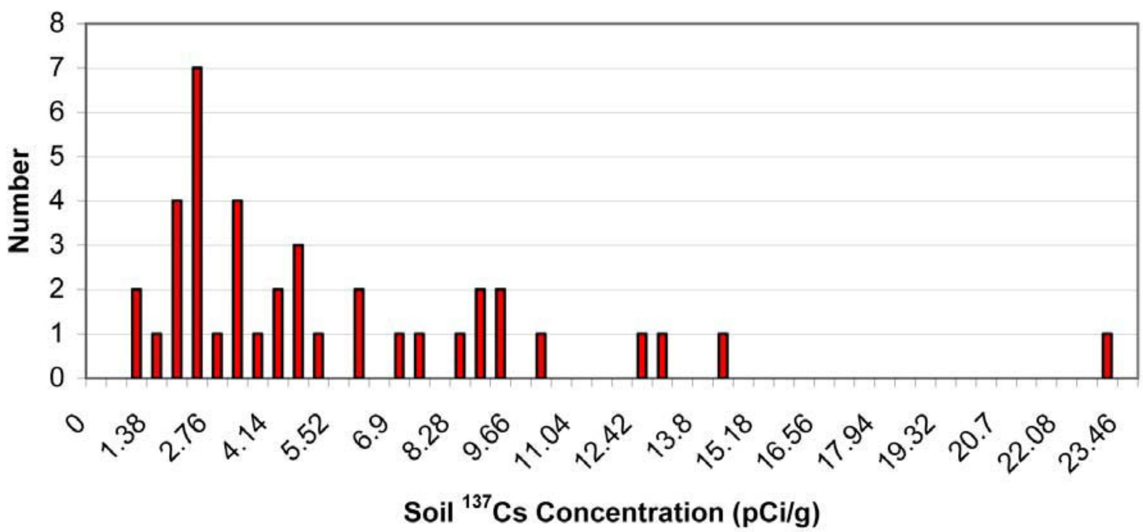

Figure 8-5. Histogram of ^{137}Cs concentration in soils in evaluation area 6 (Figure 8-4).

The histogram bars identify the number of samples with concentrations in specific ranges.

Table 8-8. Soil concentrations data, biota concentrations guides, and sums of fractions, and combined sums of fractions for biota dose assessment of terrestrial ecosystems on the INEEL. (See DOE 2002 for definitions and a detailed description of the procedure.)

Nuclide	Water BCG[a] (pCi/L)	Effluent Concentration (pCi/L)	Partial Fraction[b]	Soil BCG (pCi/g)	Soil Concentration (pCi/g)	Partial Fraction[c]	Sum of Fractions[d]
First Screening[e]							
^{241}Am				4,000	0.193	4.96×10^{-5}	4.96×10^{-5}
^{137}Cs				20	15.3	7.35	7.35
^{3}H	$2.\times10^{8}$	3.60×10^{3}	1.56×10^{-5}				1.56×10^{-5}
^{129}I	$6.\times10^{6}$	1.00×10^{-1}	1.75×10^{-8}				1.75×10^{-8}
^{239}Pu				6,000	0.0774	1.27×10^{-5}	1.27×10^{-5}
^{226}Ra				50	0.228	4.51×10^{-3}	4.51×10^{-3}
^{90}Sr	50,000	8.300	1.52×10^{-4}	20	0.179	7.96×10^{-3}	8.11×10^{-3}
^{232}Th				2,000	0.811	5.37×10^{-4}	5.37×10^{-4}
$^{233/234}$U				5,000	0.767	1.59×10^{-4}	1.59×10^{-4}
^{235}U				3,000	0.123	4.44×10^{-5}	4.44×10^{-5}
^{238}U				2,000	0.642	4.06×10^{-4}	4.06×10^{-4}
				Combined Sum of Fractions[f]			**7.36**
Second Screening (Area 15 removed)[e]							
^{241}Am				4,000	0.193	4.96×10^{-5}	4.96×10^{-5}
^{137}Cs				20	23.0	1.11	1.11
^{3}H	$2.\times10^{8}$	3.60×10^{3}	1.56×10^{-5}				1.56×10^{-5}
^{129}I	$6.\times10^{6}$	1.00×10^{-1}	1.75×10^{-8}				1.75×10^{-8}
^{239}Pu				6,000	0.0774	1.27×10^{-5}	1.27×10^{-5}
^{226}Ra				50	0.228	4.51×10^{-3}	4.51×10^{-3}
^{90}Sr	$5.\times10^{4}$	8.30×10^{0}	1.52×10^{-4}	20	0.179	7.96×10^{-3}	8.11×10^{-3}
^{232}Th				2,000	0.811	5.37×10^{-4}	5.37×10^{-4}
$^{233/234}$U				5,000	0.767	1.59×10^{-4}	1.59×10^{-4}
^{235}U				3,000	0.123	4.44×10^{-5}	4.44×10^{-5}
^{238}U				2,000	0.642	4.06×10^{-4}	4.06×10^{-4}
				Combined Sum of Fractions[f]			**1.12**
Third Screening (Area 6 removed)[e]							
^{241}Am				4,000	0.193	4.96×10^{-5}	4.96×10^{-5}
^{137}Cs				20	1.34×10^{1}	0.644	0.644
^{3}H	$2.\times10^{8}$	3.60×10^{3}	1.56×10^{-5}				1.56×10^{-5}
^{129}I	$6.\times10^{6}$	1.00×10^{-1}	1.75×10^{-8}				1.75×10^{-8}
^{239}Pu				6,000	0.0774	1.27×10^{-5}	1.27×10^{-5}
^{226}Ra				50	0.228	4.51×10^{-3}	4.51×10^{-3}
^{90}Sr	$5.\times10^{4}$	8.30×10^{0}	1.52×10^{-4}	20	0.179	7.96×10^{-3}	8.11×10^{-3}
^{232}Th				2,000	0.811	5.37×10^{-4}	5.37×10^{-4}
$^{233/234}$U				5,000	0.767	1.59×10^{-4}	1.59×10^{-4}
^{235}U				3,000	0.123	4.44×10^{-5}	4.44×10^{-5}
^{238}U				2,000	0.642	4.06×10^{-4}	4.06×10^{-4}
				Combined Sum of Fractions[f]			**0.658**

a. Biota Concentration Guide.
b. Effluent Concentration/Water BCG.
c. Calculated Soil Concentration/Soil BCG.
d. Sum of the Partial Fractions.
e. See the text for the rationale for the various screenings.
f. Sum of the Sums of Fractions. If the Combined Sum of Fractions < 1, the site passes the screening evaluation.

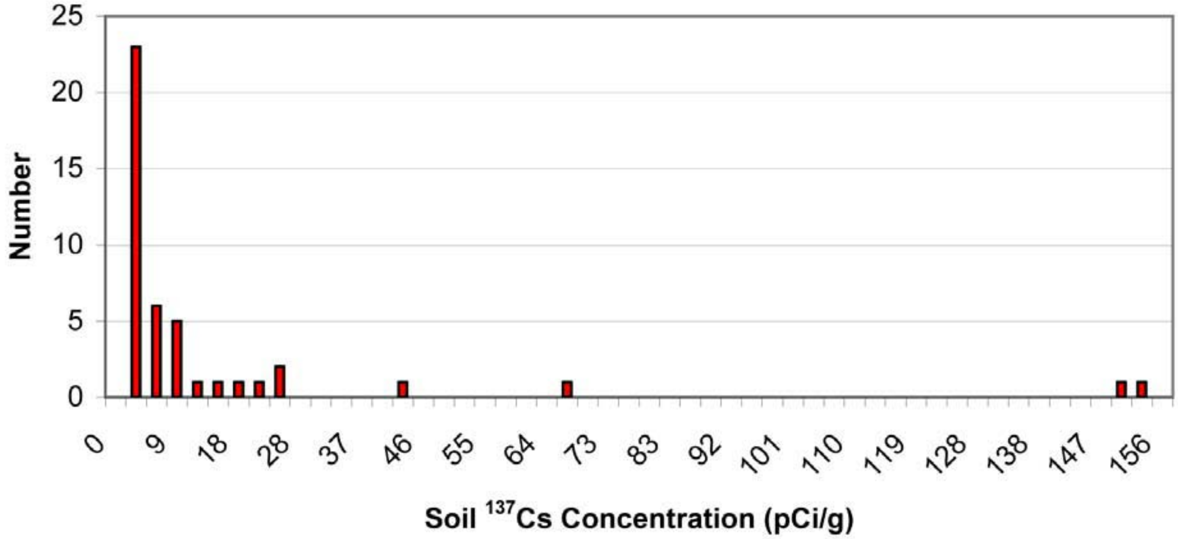

Figure 8-6. Histogram of ^{137}Cs concentration in soils in evaluation area 15 (Figure 8-4).

The histogram bars identify the number of samples with concentrations in specific ranges.

Areas 6 and 15 were evaluated separately. Because they are very large areas (Figure 8-4) with wide variation in soil concentrations and few samples with high concentrations (Figures 8-5 and 8-6), it was determined that to use the average soil concentrations was appropriate in this assessment rather than maxima. The average soil concentrations resulted in combined sums of fractions less than one (Table 8-9 and 8-10) (see DOE 2002 for a detailed description of the assessment procedure).

Based on the results of the graded approach, there is no evidence that INEEL-related radioactivity in soil or water is harming populations of plants or animals.

Table 8-9. Biota dose assessment of evaluation area 6 (Figure 8-3) on the INEEL using spatially averaged soil concentrations.

Nuclide	Water BCG[a] (pCi/L)	Effluent Concentration (pCi/L)	Partial Fraction[b]	Soil BCG (pCi/g)	Soil Concentration (pCi/g)	Partial Fraction[c]	Sum of Fractions[d]
^{241}Am				4000	0.10	2.58×10^{-5}	2.58×10^{-5}
^{137}Cs				20	4.96	0.238	0.238
^{3}H	2×10^{8}	3,600	1.56×10^{-5}				1.56×10^{-5}
^{129}I	6×10^{6}	0.10	1.75×10^{-8}				1.75×10^{-8}
^{239}Pu				6000	0.042	6.89×10^{-6}	6.89×10^{-6}
^{226}Ra				50	0.127	0.0025	0.0025
^{90}Sr	50,000	8.08	2×10^{-4}	20	0.095	0.0042	0.0044
^{232}Th				2,000	0.139	9.22×10^{-5}	9.22×10^{-5}
$^{233/234}U$				5000	0.134	2.77×10^{-5}	2.77×10^{-5}
^{235}U				3000	0.020	7.36×10^{-6}	7.36×10^{-6}
^{238}U				2000	0.091	5.75×10^{-5}	5.75×10^{-5}
						Combined Sum of Fractions[e]	**0.246**

a. Biota concentration guide.
b. Effluent concentration/water BCG.
c. Calculated sediment concentration/sediment BCG.
d. Sum of the partial fractions.
e. Sum of the sums of fractions. If the combined sum of fractions is less than one, the site passes the screening evaluation.

Table 8-10. Biota dose assessment of evaluation area 15 (Figure 8-3) on the INEEL using spatially averaged soil concentrations.

Nuclide	Water BCG[a] (pCi/L)	Effluent Concentration (pCi/L)	Partial Fraction[b]	Soil BCG (pCi/g)	Soil Concentration (pCi/g)	Partial Fraction[c]	Sum of Fractions[d]
^{241}Am				4000	0.10	2.58×10^{-5}	2.58×10^{-5}
^{137}Cs				20	13.3	0.637	0.637
^{3}H	2×10^{8}	3,600	1.56×10^{-5}				1.56×10^{-5}
^{129}I	6×10^{6}	0.10	1.75×10^{-8}				1.75×10^{-8}
^{239}Pu				6000	0.0025	4.10×10^{-7}	4.10×10^{-7}
^{226}Ra				50	0.127	0.0025	0.0025
^{90}Sr	50,000	8.08	2×10^{-4}	20	0.095	0.0042	0.0044
^{232}Th				2,000	0.139	9.22×10^{-5}	9.22×10^{-5}
$^{233/234}U$				5000	0.134	2.77×10^{-5}	2.77×10^{-5}
^{235}U				3000	0.020	7.36×10^{-6}	7.36×10^{-6}
^{238}U				2000	0.091	5.75×10^{-5}	5.75×10^{-5}
					Combined Sum of Fractions[e]		**0.644**

a. Biota concentration guide.

b. Effluent concentration/water BCG.

c. Calculated sediment concentration/sediment BCG.

d. Sum of the partial fractions.

e. Sum of the sums of fractions. If the combined sum of fractions is less than one, the site passes the screening evaluation.

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